<u>TEST REPORT</u>

CRREL PORTABLE PROPELLANT BURN PAN
PROTOTYPE BURN TEST
CAMP GRAYLING, MI

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Cover image: Test burn of 91 kg of M1 artillery propellant by 1/134th OH ARNG at FP 301, Camp Grayling, Michigan, 10 June 2013. (*M.R. Walsh, USA CRREL*)

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CRREL Portable Excess Propellant Burn Pan
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Objectives: The objectives of this test were as follows:

- Conduct a test burn of excess howitzer propellant in the prototype burn pan
- Obtain performance data for pan (weight, time to burn, capacity)
- Obtain and analyze samples of residues in pan and on soil to evaluate burn efficiency
- Demonstrate burn pan to Camp Grayling Environmental Manager and Range Officer
- Have training unit do a complete burn operation with the pan
- Obtain feedback from training unit, Range, and Environmental

Background

Munitions for indirect fire weapon systems are issued with a full complement of propellant charges, ranging from four to over 10 individual charges per round. Charge loads are varied in accordance to the desired ballistics of the fired projectile and the state of the weapon system. Excess, unused propellant charges result from the reduced charge load required for operation of a "cold" weapon system or firing at less than maximum range. Excess charges are destroyed following a training mission by burning.

The burning of excess propellant charges is typically carried out in one of three manners: Transportation to a central burn facility where specialists dispose of the charges, transportation to distributed fixed burn pans where a limited number of trainees dispose of the propellants, or burning of the charges by the training troops on the ground near the firing positions. The first option is cleanest as trained personnel conduct the burn in a generally well-maintained burn pan and can collect the residues for disposal. However, the soldiers do not gain experience burning the propellant as they would in combat and there are risks associated with transporting the propellant charges. The pans are also not specifically designed for the disposal of propellants and are not as efficient as they could be. They also require a prepared pad area for safety during the burn. The second option affords the troops with the opportunity to conduct the burn as part of their training, but transportation of the propellant limits the number of soldiers involved. Maintenance of remote fixed pans can be problematic, as can be the collection of post-burn residues. Burning of excess propellants on the ground is still conducted on many training ranges, giving the troops the most realistic and valuable training experience associated with live-fire training. However, burning on the grounds can result in up to 20% of the propellant remaining in the residues on the ground following a burn, and these residues are not collected for disposal. The residues contain toxic materials that can harm the environment and jeopardize the continued use of the range. A better alternative to these three scenarios was therefore sought.

As part of the US Department of Defense Strategic Environmental Research and Development Program project ER-1481, the US Army Cold Regions Research and Engineering Laboratory CRREL) and Defence Research and Development Canada–Valcartier (DRDC) examined alternatives to the then-current propellant burning practices. The Canadian researchers at DRDC concentrated on optimizing the fixed burn pan concept while CRREL worked on developing a portable burn pan that could be transported to a firing point where training was occurring. Working together, a general design concept was developed and tested, first using a series of the fixed Canadian pans, then with portable pans developed by CRREL. The Canadian design has been finalized and its use part of training doctrine in Canada. The portable pan was developed through the first two prototype models, performing well in both cases. In 2013, CRREL was awarded project funding by the Environmental Security Technical Certification Program through Project ER-20323 for the completion of development and demonstration of the portable burn pan concept. This test is part of the development phase of the project.

Methods

A burn pan was fabricated at CRREL based on improvements to the previous prototypes. The overall goals for the new design were a reduction in weight and an increase in burn efficiency. Additional design improvements were made to facilitate loading and ignition of the propellant. It is a simple, self-contained design with a minimum of parts **(Figure 1).**

Figure 1: Unloading burn pan from rear of medium tactical truck.

The burn pan consists of three assemblies. The base is the main component. It is a welded aluminum fabrication approximately 1-m x 2-m x 0.3-m deep on 30-cm high legs. It has handles placed on both sides of all four corners for lifting and placement of the assembled unit. A stainless steel false bottom fits into the base. It has perforated stainless sides that contain the charge bags and act as a guide for loading the charges. The false bottom serves to protect the aluminum base from the heat of deflagration of the propellant charges. The stainless bonnet fits onto the top of the pan and helps contain the burn and any debris, such as charge bag fragments, from being ejected from the pan without constricting the burn. The bonnet has a small door at one end that is used to provide access to the propellant charges for ignition. Recommended auxiliary equipment for the burn pan includes a tarp with tie-downs for storage and a flat-bottomed scoop for collection of the burn residues. Fire suppression equipment should be supplied by the appropriate entity.

Working closely with the US Army National Guard Bureau, a test site was chosen. Camp Grayling, MI, is the largest of the Army National Guard (ARNG) training facilities. This facility allows ARNG troops to train with both mortars and howitzers. Arrangements were made with Mr. John Hunt, Environmental Manager at Camp Grayling (CGMI), to conduct a test on his post. The 1/134th Ohio ARNG volunteered to participate in the tests. Coordination was through 1SG Scott Zaebst and CPT Patrick Rippeth. Planning and coordination went smoothly. The pan components were weighed prior to transportation to the test site.

Firing Point 301 on the north side of CGMI was the location at which the artillery unit was training. The firing point is a sandy, sparsely vegetated open area with low discontinuous grass. Recent rains had moistened the soil, making it cohesive. A location was chosen for the burn pan and baseline soil samples were taken to characterize the site prior to the test burns. An area 6 m in diameter was sampled in triplicate with the CRREL multi-increment (MI) sampling tool using a 3-cm coring bit set at 2-cm depth. An additional area from 3 to 6 m from the pan location center point was also sampled in the same manner. Weather was initially calm with heavy overcast and no precipitation.

Excess propellant charges were collected from the six guns of the battery undergoing training. The recent rains had wetted about half the propellant, so only the drier propellant was weighed and used for the test. Four volunteers form the unit unloaded the pan from the transport vehicle and placed it in position. CRREL technicians then attached thermocouples to the false bottom of the pan, the perforated sides of the bonnet, and the side of the pan. Two Type K thermocouples were used on each component for redundancy. The thermocouples were fed into a Campbell AM 25T solid state Thermocouple multiplexer. Data was recorded on a Campbell CR10X datalogger located in an enclosure 5 m from the pan. The enclosure was protected from the radiant heat of the propellant burn with reflective aluminum foil. The pan then loaded with propellant charges by the soldiers and the bonnet placed on the pan. Final wiring of the thermocouples was completed and the area cleared of non-essential personnel. The propellant was then initiated. The climatic conditions were recorded at the start of the burn. All activities associated with the burn procedure were timed.

Following the cessation of the burn, the pan was inspected to ensure completion of the process. Two sets of MI soil samples were taken from the same locations as the baseline samples. The bonnet was then removed and the residues collected and bagged for later processing and analysis at CRREL. Thermocouples were detached from the pan components and the bonnet replaced on the pan. The active test was then complete.

The test was observed by officers and enlisted personnel of the 1/134th, the CGMI Environmental Manger, and the CGMI Range Officer. Following the burn, each party was solicited for input on the process. The pan was then turned over to the Environmental Manager, who left it in place for further use by the 1/134th. An additional burn was conducted by senior NCOs of the unit prior to the departure of CRREL.

Soil samples and the residues were transported to CRREL for processing and analyses. Samples were set out to dry, the three sets of samples separated from each other to prevent cross contamination. When dry, the soil samples were weighed, separated into <500-g lifts, and ground for three 60-second periods with a ring and puck mill (LabTech Essa Model LMP-2) to obtain the required particle size. The ground lifts for each type of soil sample were combined, stirred, and subsampled using MI sampling (40 increments) to obtain the 10-g subsample for analysis. The subsamples were placed in a 60-mL (2 oz) wide-mouth amber jars along with 20 ml of solvent (acetonitrile) and shaken for 18 hours on a New Brunswick Scientific Innova 2100 platform shaker oscillating at 150 rpm. Analyses were conducted on a Thermo Scientific Accela high-pressure liquid chromatography –mass spectrometer (UHPLC-MS) in accordance with EPA Method 8330b. The analyte of concern for the M1 single-base propellant is 2,4-dinitrotoluene (DNT). There was no lead in the propellant bags burned during this test.

The pan residues were weighed and processed separately from the soil samples. The dried residues were weighed in total before the unburned propellant bag material was removed and weighed separately. The components were recombined and burned to simulate multiple burn activities in the pan. The final residues were weighed again and processed in the same method as the soils prior to analysis on the UHPLC–MS.

Results

The combined mass of the burn pan is 115 kg. This is a reduction of 12 kg from the previous prototype and 110 kg less than the original “portable” burn pan. We have met the project objective for the total mass of the burn pan of less than 120 kg. The mass of the pan base is 46 kg, the false bottom 39 kg, and the bonnet 30 kg, all well under the 70 kg individual component weight target set out in the ESTCP requirements. The complete unit was easily handled by four soldiers and individual components were easily handled by two. Maximum lifting height was 1.5 m in and out of the transport vehicle.

Climatic conditions were good at the start of the burn sequence. There was a heavy overcast with intermittent mist. The area was damp from a previous rain event. The temperature was 20°C with a 1.3 – 2.2 m/s wind. Just as the charges were about to be lit, the wind picked up to approximately 12 m/s and heavy rain started. These are probably worst-case conditions for a burn event.

Each event in the burn sequence was individually timed. The rain, which began seconds before the start of the burn, extinguished the first ignition attempt, although the second attempt was successful. Ignition was initiated by cutting open several charge bags, emptying the bags at one end of the pan on top of the other bags, and lighting one end of the exposed propellant grain pile with a butane lighter. **Table 1** describes the sequence and timing of the events.

Table 1: Timed sequence of events for test burn

Event	Time (m:s)	Elapsed Time (m:s)
Placement of pan	1:20	1:20
Loading of pan	3:50	5:10
Lighting propellant*	2:08	7:18
Burn	0:42	8:00
Cool down (<100°C)	3:20	11:20
Residues collection	1:40	13:00
Return pan to vehicle	1:20	14:20

*Heavy rain extinguished first of two propellant initiation attempts

The propellant charges were massed on an electronic scale prior to loading in the burn pan. An equal number of charges 6 and 7 (250 g and 408 g) were burned. The total mass loaded for the test was 90 kg, equal to approximately 136 sets of charges. The charge bags were damp to dry when loaded but quickly became saturated on the tops because of the heavy rain that started just as the charges were being lit.

The burn temperatures are depicted in **Figure 2**. There is a rapid rise in temperature following initiation. The maximum recorded temperature was 562°C at the downwind perforated bonnet thermocouple location **(Table 2).** The upwind location was 170°C cooler as the wind drove the burn flames towards the downwind thermocouple location. The maximum temperatures on the side of the pan reached 126°C before cooling down. Again, the downwind temperature was greater than the upwind. The false bottom reached a maximum temperature of 160°C. Maximum temperatures are likely higher than those recorded because of the thermal lag due to the burn pan component materials, especially the stainless steel. Cool-down was considered attained when all thermocouple outputs were below 100°C, approximately four minutes after the burn was complete. The system did not return to ambient during the recording period (5 minutes).

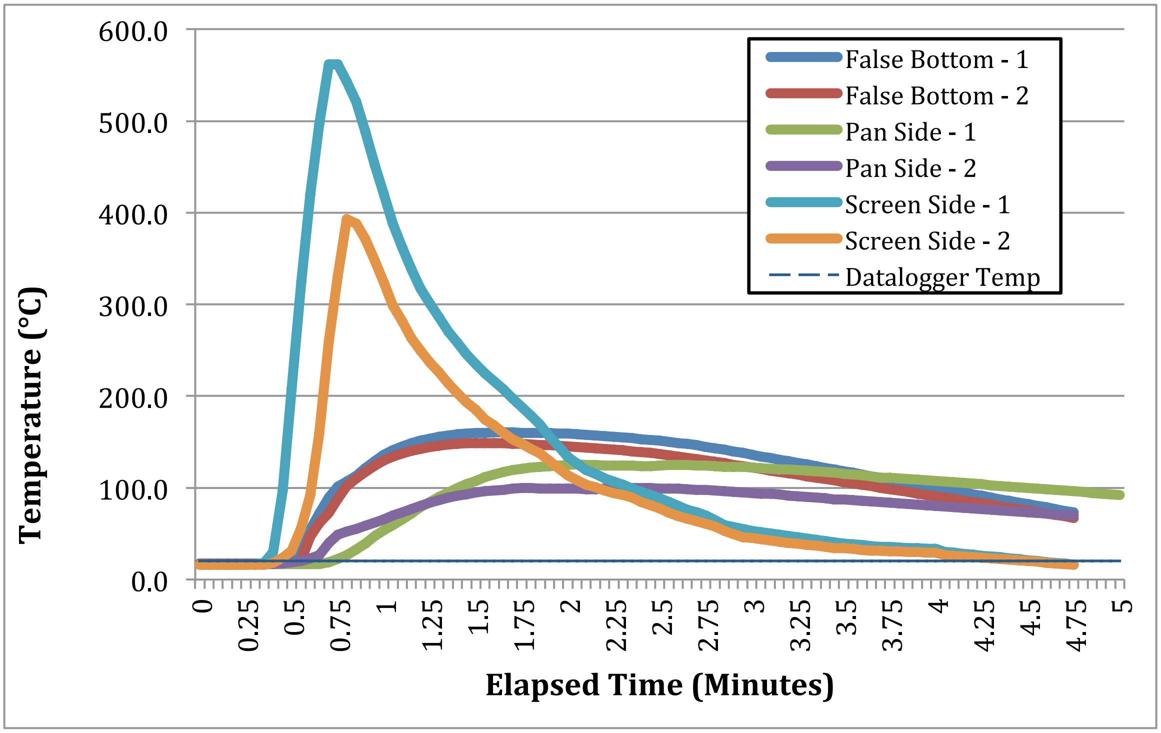

Figure 2: Temperatures of burn pan components during a burn.

Table 2: Location of thermocouples

Thermocouple	Location
False Bottom – 1	Centerline of false bottom: 60 cm from access door end of pan
False Bottom – 2	Centerline of false bottom: 140 cm from access door end of pan
Pan Side – 1	15 cm from bottom of pan: 60 cm from access door end of pan
Pan Side – 2	15 cm from bottom of pan: 140 cm from access door end of pan
Screen Side – 1	30 cm from top of bonnet: 60 cm from access door end of pan
Screen Side - 2	30 cm from top of bonnet: 140 cm from access door end of pan

Soil samples were analyzed for both 2,4- and 2,6-DNT. **Table 3** summarizes the results. The data shows that DNT contamination existed at the burn pan location prior to the test. It also shows that there was no measurable increase in DNT concentration in the soil surrounding the burn pan in either the 0-3 m annulus or the 3-6 m annulus following the 91-kg test burn. The original mass of DNT in the charges burned was approximately 8 kg. These results demonstrate that less than 0.01% of the DNT in the burn was deposited as residue on the soil surface surrounding the burn pan. The performance goal of <0.01% for the burn pan was thus met.

Table 3: Soil concentrations of DNT before and after test burn (mg/kg)

		0 to 3 m Annulus	3 to 6 m Annulus
Pre-burn	Rep 1	0.26	0.62
	Rep 2	1.2	1.3
	Rep 3	3.9	0.92
	Mean	1.8	0.95
Post-burn	Rep 1	2.7	0.19
	Rep 2	0.38	0.15
	Rep 3	1.7	1.7
	Mean	1.6	0.68

Results from a Wilcoxon-Mann-Whitney Rank Sum Test analysis of the data sets indicates that there is no statistical difference between the pre-burn and post-burn soil sample results for the analyte DNT. The P value for the 1- to 3-m annulus is 1.0 and for the 3- to 6-m annulus the P value is 0.7, both well above the 0.05 thresh-hold for statistical difference. There is also no statistical difference between the pre- and post-burn data sets for the two sampled annuli.

Residues retained within the pan were measured after drying and the masses broken out as depicted in **Table 4**. The initial combustible mass of the 91-kg burn was 90.1 kg. The initial mass of the residues (wet) was 500 g. Following the drying of the collected residues, the mass remaining was 270 g, a 54% reduction in mass. Of this total mass, 90 g consisted of visually identifiable combustible materials (propellant grains and charge bag remnants), which were sorted from the general ash material.

Table 4: Mass reduction from the propellant burn

	Pre-burn Mass (Kg)	Mass After **Initial** Burn (g)	Mass After **2nd** Burn (g)	Difference
Charges	91			
Combustibles	90.1	500		
Total residues (dry)		270	200	70 g /26%
Bag remnants		15	9.2	6.2 / 41%
Propellant grains		75	15	60 g / 80%
Ash		180	180	0 g / 0%
% Reduction – Mass		99.7%	99. 8%	
– Combustibles		≈99.91%*	100%	0.09%

* Estimate based on remaining combustible materials (bags and propellant)

Following a re-burn of the three sorted residues fractions, the final total residue mass was reduced to 200 g. Using the 270 g mass of the material combusted after drying the residues, the efficiency of the burn in reducing the combustible mass was 99.92%. The 0.08% of combustible mass remaining after the initial burn in the pan is less than the 0.1% goal of the project. Note that up to 1% (910 g) of the original burn pan load was non-combustible potassium sulfate, a flash suppressant in the propellant charges.

The remaining residues from the second burn were brought to the analytical lab for DNT analyses. Each component was analyzed separately (**Table 5**). The total mass of DNT in the original combined charges was approximately 8,000 g (9%). The final mass of DNT in the residues was 1.5 g, or 0.02% of the original mass of DNT for the burn. There is no performance goal for DNT in the pan residues. The final volume of the residues was less than a liter.

Table 5: Dinitrotoluene in final pan residues

	Residue Mass (g)	Mass of 2,4-DNT (g)	Mass of 2,6-DNT (g)	Percent of Residue Mass
Ash	180	1.400	0.057	0.89%
Propellant grains	75	0.021	0.0012	0.03%
Bag remnants	15	0.0046	0.0004	0.03%
Total	270	1.4	0.059	0.44%

Figure 3: Soldiers of the Ohio ARNG leveling propellant charges for the 91 kg test burn.

User Feedback

User feedback was an essential component of the testing at CGMI. This feedback will be used to refine the equipment design and develop the protocol for the use of the pans. The following is feedback obtained at CGMI from the interested parties as well as some observations from the CRREL test staff.

- **CGMI Environmental Manager (Mr. John Hunt)**
  - Liked the concept very much
  - Small size and portability are assets
  - Will control and require the use for all indirect fire training utilizing propellant charges.
  - Would like to obtain more burn pans or drawings so more can be built
  - Will cancel requirement for an additional fixed burn pan at CGMI

- **Range Officer (SSG Shaun Regier)**
  - Concept seemed to work quite well
  - Need to locate the burn pan in an area of no vegetation
  - Will need to issue fire suppression equipment with the burn pan

- **Training Unit (1/134th OH ARNG)**
  - An additional set of lifting handles at midpoint of pan would be convenient
  - Liked perforated sides on false bottom, used as loading guides
  - Appreciated the ability to burn propellant on site
  - Saw the presence of the burn pan as a great training opportunity for the soldiers
  - Quite comfortable with using the pan after minimal training
  - Felt that using the pan would increase training efficiency
  - Requested the burn pan remain so they could use it for the two batteries over the course of their training at CGMI

Other Possible Improvements (CRREL)

- Replace removable legs with permanent legs
- Put drain holes with plugs in bottom corners of pan
- Thin stainless angle on top of bonnet to reduce sharp edges
- Install lift handles on bonnet

After-action Tasks (CRREL)

- Modify drawings with changes
- Send a set of drawings to Mr. Hunt
- Test report copies to ESTCP, CGMI, OH ARNG, and ARNG Bureau

Suggested Procedure for the Utilization of the Portable Burn Pan on Ranges

1. Burn pan signed out and transported from holding facility to firing point
2. Location of burn pan demarcated based on input from Range or RSO/OIC (Factors: Safety, fire hazard, levelness)
3. Burn pan placed at demarcated location (Cover with tarp if raining or rain predicted)
4. Fire suppression equipment placed 100 m from burn pan
5. Excess propellant charges are generated through training (Keep all charges dry)
6. At a break in firing or cessation of training, assign propellant burn duties to two to four soldiers
7. Move propellant bags from firing positions to ≈100 m from burn pan
8. Remove the tarp (if present) and perforated bonnet from the base of the burn pan
9. Load the burn pan with charges (Maximum height of the charges is the top of the inner perforated screen on the false bottom)
10. Cut open sufficient propellant bags (3 min) and pour grains on top of the propellant bags at the end of the pan that holds the access door on the bonnet
11. Replace the bonnet on the pan
12. Open the access door on bonnet
13. Position one soldier at either end of burn pan
14. Soldier at access door end lights the propellant grains, closes the access door
15. Confirm ignition of the propellant grains
16. Walk 50 m minimum from the burn pan: Observe the burn
17. When the burn is complete, wait one minute and approach the pan to verify
18. Wait for cool down (≈5 minutes) before the next task
19. If there are more propellant charges to burn, reinitiate the sequence at Step 6
20. If this is the final burn, remove the bonnet and scrape up the residues. Place the residues in a heavy polyethylene bag. Label, tag, and ty-wrap the residues bag (Date, type of propellant, training unit, OIC).
21. Check the temperature of the pan. Replace the bonnet and tarp on the burn pan.
22. Return the burn pan and residues to the transport vehicle
23. Transport and turn in the residues and burn pan to the holding facility

Summary

The test of the third prototype of the CRREL portable burn pan was very successful. All project goals that were relevant were achieved or succeeded. The final volume of the residues from the burning of the 91 kg of propellant charges was less than a liter and contained only 1.5 g of DNT. There was no measureable difference in DNT concentrations in the soil surrounding the pan following the test burn. The sponsoring facility representative, Mr. John Hunt, agreed to keep and use the burn pan for further training missions and requested additional pans if available. An additional fixed burn pan he had been considering has been put on hold. Mr. Hunt requested a copy of the drawing for the burn pan. The artillery battalion requested the burn pan be left at their firing point for the duration of their deployment so they could train on burning propellant.

The portable burn pan is efficient, easy to use, and can be used as a training aid, all the while helping maintain range sustainability by greatly reducing ground contamination and allowing the efficient collection and control of toxic residues. At Camp Grayling, it is a welcome addition to their range and environmental toolbox.

Test Participants

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CGMI: John W. Hunt, SSG Shaun Regier

1/134th OH ARNG: 1SG Scott R. Zaebst, CPT Patrick J. Rippeth

ARNG Bureau: Dr. Bonnie Packer